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OSCILLOGRAPH FOR SCHOOL WORK

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/Figures referred to are appended./

In studying electrical processes, it sometimes becomes necessary to observe several oscillations simultaneously on the oscillograph screen to make a graphic comparison between their magnitudes, forms and -- what is even more important -- to follow the phase displacements between them.

Many different schemes have been suggested to show several oscillations simultaneously on a cathode-ray oscillograph. The basic idea of all the schemes amounts to the design of a switch by means of which several of the processes under examination can be alternately presented on the screen of the cathode-ray tube at given intervals of time. If the speed of the switch is sufficient, all the alternating processes will appear on the tube screen simultaneously.

The author assembled the so-called thyratron switch, described by A. I. Gordiyenko in the journal Izvestiya elektropromyshlennosti slabogo toka, No 6, 1940. The principal schematic diagram of this switch, de-signed to demonstrate three processes simultaneously, is shown in Figure 1.

The thyratron switch consists of three main parts: input amplifier tubes, thyratron circuit, and sharp-pulse generator.

The input amplifier tubes (L_1, L_2, L_3) have a common plate load resistor R_9 from which the oscillations under examination are delivered to the oscillograph input. The number of input amplifier tubes correspond with the number of processes to be simultaneously studied. At any instant, only one tube may operate, while the others are locked by the grid bias produced by the common automatic bias resistor R_8. The magnitude of each of the oscillations under observation can be varied by means of the potentiometers R_7. The potentiometers R_2 fix the operating point of each of

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the amplifier tubes and, consequently, the height of each wave within the limits of the tube screen. All the voltages studied are applied to the input terminals I, II, and III. One pair of input terminals is mounted on the case.

The number of thyratrons and thyratron circuits equal the number of input tubes. Each thyratron (T_1, T_2, T_3) fires successively, thus causing one of the amplifier tubes to conduct. After a certain period of time, the thyratron cuts off; simultaneously the next thyratron fires and, in turn, causes another amplifier tube to conduct, etc. During the operation of the thyratron circuit, rectangular voltage pulses are produced across resistors R_2 and R_3 which cause the input amplifier tubes of the switch to conduct.

The sharp-pulse generator T_4 is a conventional thyratron relaxation oscillator, the sharp pulses of which (produced by the discharge of capacitor C_2) control the thyratron circuit. The frequency of these pulses may vary within certain limits: smoothly with a variation in R_{14}, and in jumps when the additional capacitance C_{11} is switched in.

The thyratron switch is fed from an ac line through a rectifier. The current consumption is small, since only three tubes operate at the same time -- the sharp-pulse generator, one thyratron circuit, and one amplifier tube. All the other tubes are cut off.

Practical work with this switch proved its comparative simplicity, easy operation, and reliability.

Some actual applications of a thyratron switch are given below. In studying alternating currents in a course on electrical engineering, the greatest difficulty is in explaining phase relations between currents and voltages in a circuit with RLC components. Measuring instruments (ammeters and voltmeters) cannot completely reflect phase displacements, while a phase meter, which make it possible to measure the magnitude of phase displacement, cannot show the displacement itself. Therefore a cathode-ray oscillograph and thyratron switch are most useful in such applications.

Demonstration of Curves Which Are in Phase

To demonstrate voltage curves in phase with the current, i.e., in purely resistive circuits, the schematic diagram in Figure 2 can be utilized.

The ac line voltage is applied to the potentiometer R_n ($\sim$1,000 ohms), 10-20 v are taken from it. The slide-wire rheostats R_1 and R_2 are connected in series. The voltage from resistor R_1 (200-400 ohms) is applied to input I of the thyratron switch, the voltage from resistors R_1 and R_2 (500-1,000 ohms), input II; the function of input III is to trace horizontal lines (time axes) on the tube screen.

The order of the demonstration is as follows. First, the cathode-ray oscillograph and the thyratron switch are switched on, and the first straight line (time axis) appears on the screen. Next, when the lead from R_1 is attached, the circuit is connected and a sinusoidal curve is obtained on the screen, the amplitude of which can be varied by regulating R_n, R_1 and R_7 (Figure 1). Then after connecting resistance R_2, we shall obtain a second sinusoidal curve in phase with the first curve, the amplitude of which can vary within wide limits by varying R_2. The resistances can also be connected in parallel. In this case, the curves on the screen have the same period but are independent as to amplitude, each one being able to vary from zero to the maximum value fixed by the dimensions of the tube screen.

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Demonstration of Curves With a Phase Displacement Angle of 0° to 90°

The phase difference between the current and voltage in a circuit when resistive and reactive components are connected in series can be measured by the circuit shown in Figure 3.

If the reactance is inductive X_L, the phase displacement will vary from 0° to plus 90°; if it is capacitive X_c, the phase displacement will vary from 0° to minus 90°.

The voltage taken from the resistance R is always in phase with the current and, therefore, the curve corresponding to the voltage drop in it can be taken as the current curve. The voltage taken from R and X_L or R and X_c, connected in series, is the voltage curve. By changing the relation of R and X_L or X_c, it is possible to obtain two curves at differing phase angles. /Order of demonstration is similar to above./

Demonstration of Curves With a Total Phase Displacement Angle of 0° to 180°

The hookup in Figure 4 can be used to study a circuit with X_L and X_c connected in parallel and also the phase relationships between the voltages across R, X and Z, as well as the relationships between their amplitudes when tuning the circuit to resonance.

Specifications for the circuit and the general order of switching it in are the same as for the circuit in Figure 3 (for 50 cps, L=2h, R= 100-200 ohms, C =15-20 mfd; for higher frequencies L and C are correspondingly smaller.)

Demonstration of Curves With a Phase Displacement Angle of 0° to 360°

Phase displacement in a complicated oscillatory circuit, consisting of two parallel branches, each with X_L and X_c, can be studied by means of the circuit shown in Figure 5.

After applying the voltages from X_{c1} and X_{L2} to the inputs of the thyratron switch, it is possible to obtain voltages with a phase displacement angle of 0° to 180° and 180° to 360° (similar circuits are used in communications engineering under the name of "phase shifters").

While operating the thyratron switch described above, the author developed a special attachment (Figure 6) which made it possible to study the phase relationships in all the above-mentioned circuits without requiring changes in the hookup during the course of the demonstrations.

All circuit elements are mounted on the same panel, and all the switches, both in the circuits and for the inputs to the thyratron switch, are controlled by two keys K_1 and K_2 (Figure 2).

When key K_1 is in position 1 and K_2 is in position 3, a circuit is produced consisting of R_1 and X_L components connected in series (Figure 3). When key K_1 is in position 3 and K_2 is in position 1, a circuit is produced consisting of R_1 and X_{c2} connected in series. When keys K_1 and K_2 are in position 1, a circuit is produced (Figure 4), consisting of R_1 in series with the parallel-connected X_{L1} and X_{c2}. Finally, when K_1 and are in position 2, a circuit is produced consisting of two parallel branches with X_{L1} and X_{c1}, X_{L2} and X_{c2} connected in series within each branch, respectively (Figure 5).

This article has described only a few of the circuits which can be utilized to show phase displacements in the simplest electric circuits, but even this short list suffices to show how greatly a thyratron switch increases the possibilities of using a cathode-ray oscillograph in school work.

/Appended figures follow:/
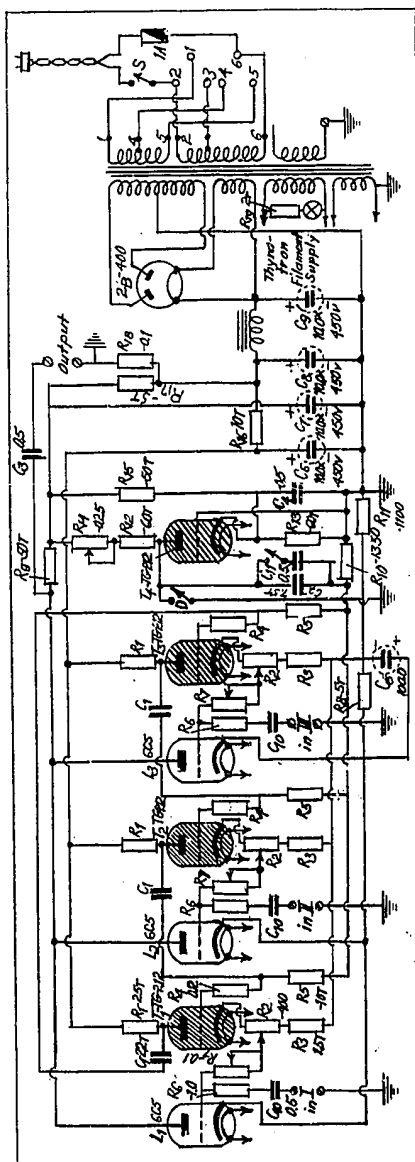
Figure 1

Note T=5000 ohms
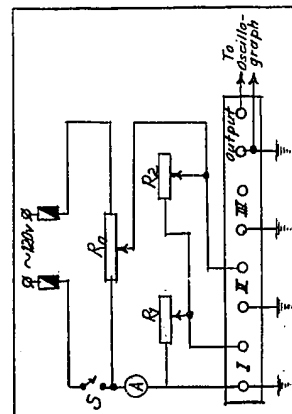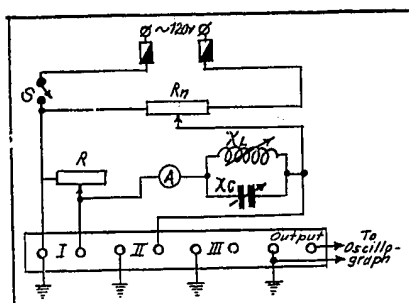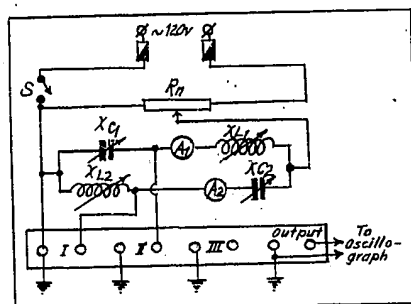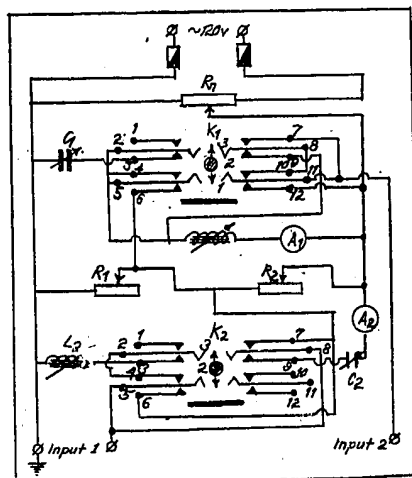

Figure 3

Figure 2

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Figure 4

Figure 5

Figure 6

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